Evaluation of Different Hybrid Energy Potential in AL-Arish

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ABSTRACT
This paper presents the potential impact of various energy generation utilizing wind turbines, photovoltaic cell, fuel cell and diesel generation for AL-Arish, Sinai, Egypt. In addition to investigating the feasibility for each combination where they are simulated using Hybrid Optimization Modeling for Energy Renewable (HOMER) software to find the optimum size for each unit and its corresponding economics.

Keywords
HOMER Software, Wind Turbine, PV, Battery, Diesel Generator, Fuel Cell.

1. INTRODUCTION

Using fossil fuels like petroleum and coal as energy resources produce a bad effect on the environment in emission of harmful gases specially carbon dioxide as well as their high prices and these resources started depleting in the oil-producing countries [1 →3].

Renewable resources as wind and solar energy are clean, freely-available and permanent, although they are un-predictable. The combination of renewable resources is widely used as an alternative for fossil fuel resources, especially in remote sites where it's becoming more promising. Usually the hybrid combination consists of two or more resources, controller, converters and a storage system [4].

2. HYBRID SYSTEM COMPONENTS
The hybrid system after the prefeasibility study consists of the following components:

1) BWC Excel-R wind turbine.
2) CHSM 6610P-250 photovoltaic panel.
3) Trojan L16P Battery.
4) Converter.
5) Fuel Cell.
6) Diesel generator.
7) AL-Arish Load.

2.1. Wind Turbine:
In this simulation, Bergey Wind Power's BWC Excel-R model is considered. It has a rated capacity of 7.5 kW and provides 48 V DC as an output. Its initial cost is $28500 and its replacement at$24500 [5]. Annual operation and maintenance cost is $200. Its lifetime is estimated at 20 years, a number from 1 unit to 10 is considered.

2.2. Photovoltaic module:
CHSM 6610P-250 photovoltaic panel is considered in the scheme, with initial and replacement cost $ 265 with rated power 250 watt and rated voltage 30 V [6] sizes to be considered are (0.25 0.5 1 1.5 2 2.5 3 3.5 4 4.50 5 5.5 6 6.5 10 20 30 40 50 60 100) watts.

2.3. Battery
Trojan L16P Battery models (6 V, 360Ah, 1.075 kWh), Cost of one battery is $275 and maintenance cost $3 [7], a number of units considered are (10 20 50 100 150 200 250 300).

2.4. Converter
For a 1 kW converter the installation and maintenance costs are taken as $1000 and $10, number of units to be considered (1 2 3 4 5 6 10 20 30 50 100 150 200) KW

2.5. Fuel Cell
A fuel cell is an energy conversion device, which converts the chemical energy of a fuel and oxidant, often hydrogen and oxygen, to electrical energy. Fuel cells are similar to batteries, however, unlike battery a fuel cell must be continuously provided with fuel, with initial and replacement cost $3000 and $2700 respectively, for 1KW size and operation and annual maintenance cost $0.02 [8] sizes to be considered are (1 2 3 4 5 6 7 10 15 20) KW.

2.6. Diesel generator.
The diesel generator sizes to be considered in simulation vary from 3 to 7 kW. Their initial costs and replacement cost are respectively (2990, 2400$), (3978, 3200$), (4984, 4000$), (5981, 4800$) and (6978, 5600$). Their operation and maintenance are of 0.05$/h [9]

2.7.AL-Arish Load:

The annual peak load is 11 KW with energy consumption of 85 kWh/day and the daily profile of the load is shown in Fig. 1.
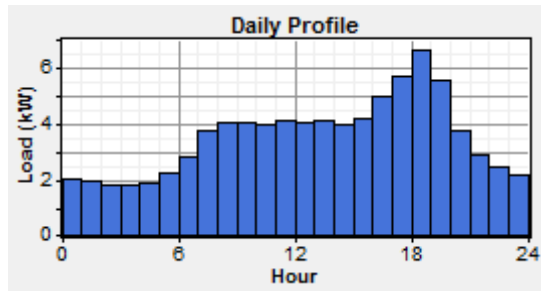

Fig.1: AL-Arish Load Profile.

3. WIND AND SOLAR RESOURCES:

The annual average wind speed and the annual average insolation level at AL-Arish is 5.29 m/s and 5.71 kWh/m^2/day, respectively. The monthly wind speed variation, the monthly clearness index and the daily radiation are shown in Fig. (2, 3) [10].
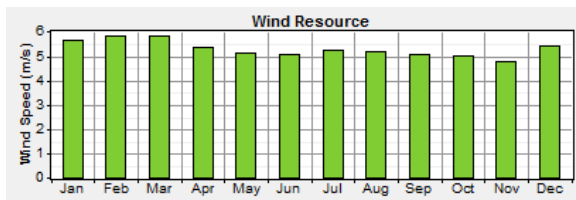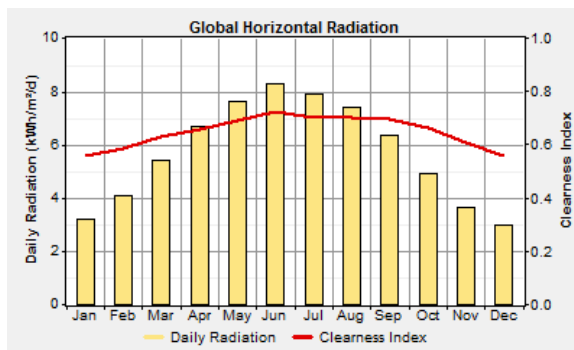

Fig.2: AL-Arish Wind Speed

Fig.3: AL-Arish Solar Irradiance

4. SIMULATION OF HYBRID SYSTEMS WITH HOMER SOFTWARE:

HOMER software simulates the operation of the proposed system along the year by making an energy balance between the generation and the load to determine the feasible system architecture which meet the load demand under the site condition beside specifying the cost-effective combination based on the total net present cost [TNPC] which is the summation of all the costs and revenue all over the project life time which is assumed 25 years [11].

Where the cost of each element is given by:

Ci= Ni * [CCosti + RCosti * Ki + OMCosti]

i= PV, Wind Turbine, Diesel Generator, Fuel Cell, Battery and Converter.

Where Ni is the number/size of the system component, CCosti is the capital cost, RCosti is the replacement cost, Ki is the number of replacement, and OMCosti is operation and maintenance cost through the system operation.

Number of combinations are to be considered as follows:

1. Wind turbine, Batteries and Diesel generation.

2. PV panel, Batteries and Diesel generation.

3. Wind turbine, Batteries and PV panels.

4. Wind turbine, Batteries, PV panels and Diesel generation.

5. Wind turbine and Fuel cell

6. PV panels and Fuel cell

7. Wind turbine, PV panels and Fuel cell.

Then simulated using HOMER software to determine the most optimum combination for AL-Arish load.

4.1.Wind and Diesel generation

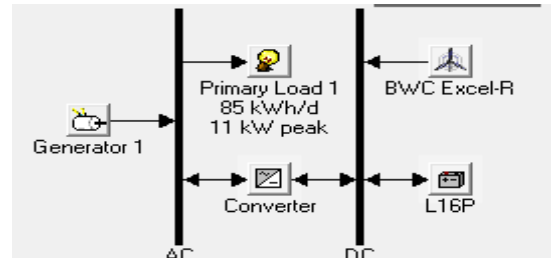The Fig.4 shows Wind and Diesel System Design Using HOMER.

Fig.4: Wind and Diesel System.

The simulation results present the optimum combination: 1 wind turbine, 4KW generator, 10 batteries and 4KW converter as shown in Table. (1), with initial cost: 33,228$, operating cost: 7,208$/year and cost of energy: 0.335$/kWh, Fig (5) shows the energy yield of the optimum solution.

Table.1: Wind and Diesel Optimization Result.

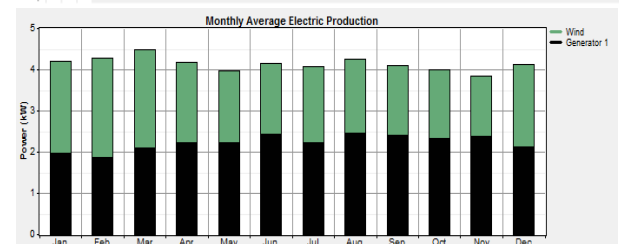|	XLR	Label (kW)	L16P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Diesel (L)	Label (hrs)
	1	4	10	4	$ 39,228	7,208	$ 131,371	0.335	0.46	0.02	6,913	6,298

Fig.5: Wind and Diesel Electric Production

4.2. PV and Diesel generation

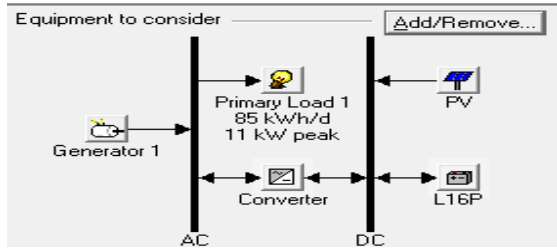The Fig.6 shows PV and Diesel System Design Using HOMER.

Fig.6: PV and Diesel System.

The simulation results present the optimum combination: 20KW PV, 2KW generator, 50 battery unit and 6KW converter as shown in Table. (2) and Fig. (7) shows the energy yield of the optimum solution.

Table.2: Wind and PV Optimization Result

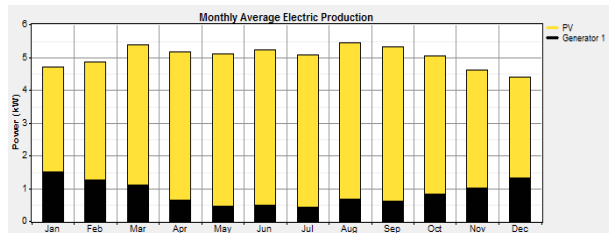|			PV (kW)	Label (kW)	L16P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Diesel (L)	Label (hrs)
			20.00	2	50	6	$ 42,772	5,859	$ 117,664	0.299	0.82	0.02	2,676	4,390

Fig.7: Wind and PV Electric Production

4.3. Wind and PV.

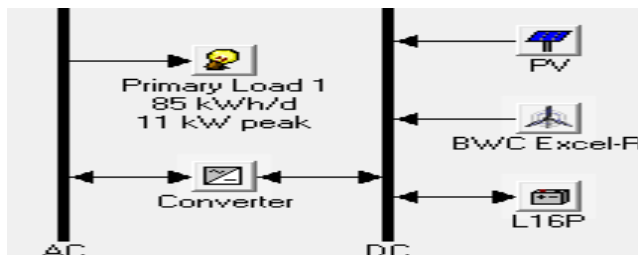The Fig.8 shows Wind and PV System Design Using HOMER.

Fig.8: Wind and PV System

The simulation results present the optimum combination: 20KW, 1 wind turbine, 50 battery unit and 10 KW converter as shown in Table. (3), and Fig. (9) shows the energy yield of the optimum solution.

Table.3: Wind and PV Optimization Result

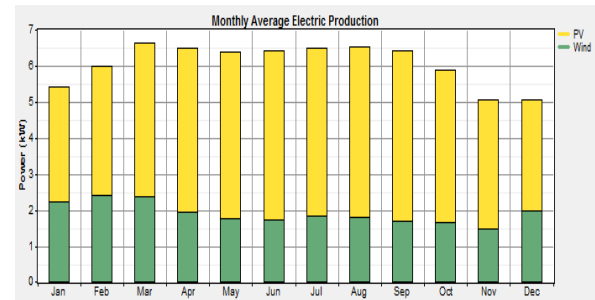|				PV (kW)	XLR	L16P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage
				20.00	1	50	10	$ 73,450	3,305	$ 115,701	0.296	1.00	0.02

Fig.9: Wind and PV Electric Production.

4.4.Wind, PV and Diesel

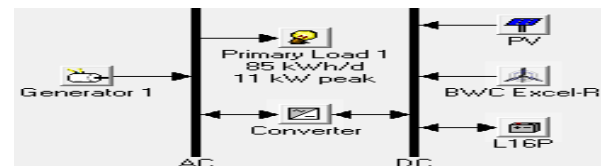The Fig.10 shows Wind , PV and System Design Using HOMER.

Fig.10: Wind, PV and Diesel System

The simulation results present the optimum combination: 11 KW PV, 1 wind turbine, 2KW generator, 30 battery unit and 6 KW converter as shown in Table. (4) and Fig. (11) shows the energy yield of the optimum solution.

Table.4: Wind, PV and Diesel Optimization Result

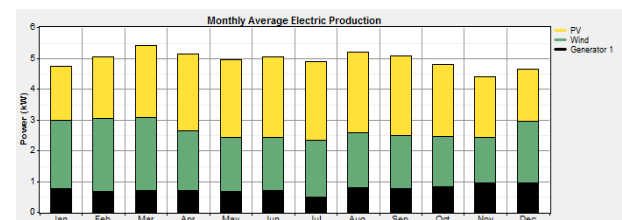|					PV (kW)	XLR	Label (kW)	L16P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Diesel (L)	Label (hrs)
					11	1	2	30	6	$ 56,232	4,364	$ 112,014	0.284	0.85	0.01	2,228	3,605

Fig.11: Wind, PV and Diesel Electric Production

4.5. Wind Turbine and Fuel Cell.

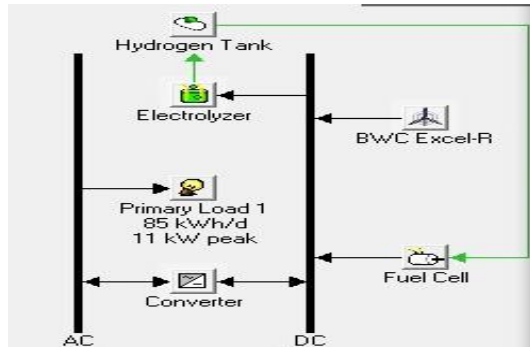The Fig.12 shows Wind and Fuel System Design Using HOMER.

Fig.12: Wind and Fuel Cell System

The simulation results present the optimum combination: 6 BWC wind turbine, 6 KW Fuel Cell, 10 KW converter, 10 KW Electrolyzer and 20 kg hydrogen tank as shown in table (5) and Fig. (13) shows the energy yield of the optimum solution.

Table.5: Wind and Fuel Cell Optimization Result

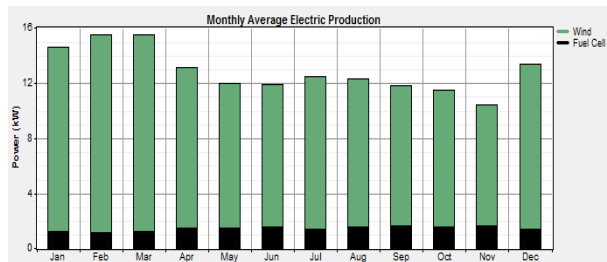|	XLR	FC (kW)	Conv. (kW)	Elec. (kW)	H2 Tank (kg)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	FC (hrs)
	6	6	10	10	20	$ 245,000	8,965	$ 359,598	0.915	1.00	0.02	4,548

Fig.13: Wind and Fuel Cell Electric Production

4.6. PV panels and Fuel cell.

The Fig.14 shows PV and Fuel System Design Using HOMER.
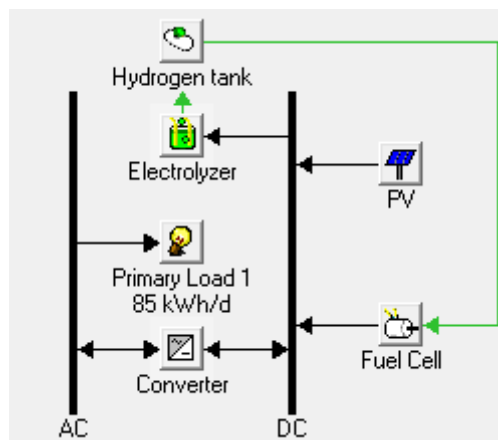

Fig.14: PV and Fuel Cell System

There is no optimum solution found

4.7. Wind turbine, PV panels and Fuel cell.

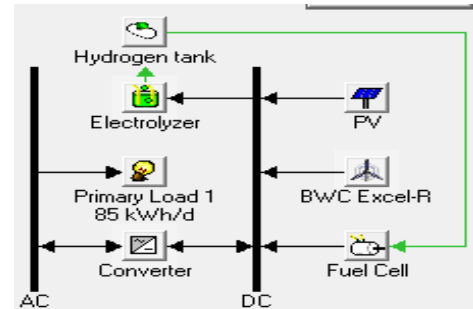The Fig.15 shows Wind, PV and Fuel System Design Using HOMER.

Fig.15: Wind, PV and Fuel Cell System

The simulation results present the optimum combination: 40 KW PV, 2 BWC wind turbine, 6 KW Fuel cell, 10 KW Converter (Inverter & Rectifier), 10 KW Electrolyzer and 10 Kg hydrogen tank as shown in table (6) and Fig. (16) Shows the energy yield of the optimum solution.

Table.6: Wind, PV and Fuel Cell System Optimization Result

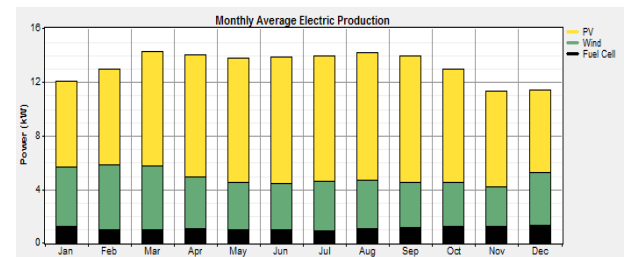|	PV (kW)	XLR	FC (kW)	Conv. (kW)	Elec. (kW)	H2 Tank (kg)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	FC (hrs)
	40.00	2	6	10	10	10	$ 160,400	6,701	$ 246,061	0.626	1.00	0.02	3,922

Fig.16: Wind, PV and Fuel Cell Electric Production

5. LOAD SHEDDING

Load Shedding is a preferred method of saving energy for the grid. During certain times of the day, or during emergencies, large consumers of electricity will reduce their electricity usage, thus reducing the load on the grid.

This can save the cost of having extra generators and reduce the cost of electricity for consumers.

For AL-Arish load a percentage of 20% of the peak load is reduced for the peak months (April, August) on the peak hour (18:00 → 19:00)

6. CONCLUSIONS

The previous cases are summarized in table (7) showing the system architecture and economic value.

The results show that the combination including diesel generators (as: wind &diesel, PV & diesel and wind & PV& diesel) gives less net present cost than its corresponding combination with fuel cell (as: wind &fuel cell, PV & fuel cell and wind & PV & fuel cell)

PV and Fuel cell doesn't present any optimal solution.

The most optimum combination is wind, PV and diesel with lowest net present cost and energy cost so load shedding was

applied at the peak load to reduce twenty percent, which results in reducing the net present cost from $112014 to $107880 and reduce the energy cost from $/KW 0.284 to $/KW 0.275, the system architecture changed from: 11 KW PV, I wind turbine, 2 KW diesel generator and 30 battery unit to 12 KW PV, 1 wind turbine, 3 KW diesel generator and 28 battery unit.

Table.7: Comparison between Different Hybrid Combinations

System	Architecture	Net Present Cost($)	Cost of energy ($/kwh)
Wind and Diesel	1BWC WT 4KW generator 10L16P battery 4 KW converter	131371	0.335
PV and Diesel	20KW PV 2KW generator 50 L16P battery 6 KW converter	117664	0.299
PV and Wind	20KW PV 1BWC WT 50L16P battery 10 KW converter	115701	0.297
PV, Wind and Diesel	11KW PV 1BWC WT 2KW generator 30 L16P battery	112014	0.284
Wind and Fuel Cell	6 BWC WT 6 KW FC 10 KW Converter 10 KW Electrolyzer 20 Kg Hydrogen Tank	245000	0.915
PV and Fuel Cell	No Optimal Solution	No Optimal Solution	No Optimal Solution
Wind, PV and Fuel Cell	2 BWC WT 40 KW PV 6 KW FC 10 KW Converter 10 KW Electrolyzer 10 Kg Hydrogen Tank	160400	0.626

7. REFERENCES

[1] Mohamed El Badawe, Tariq Iqbal & George K. Mann, (2012) "OPTIMIZATION AND A COMPARISON BETWEEN RENEWABLE AND NONRENEWABLE ENERGY SYSTEMS FOR A TELECOMMUNICATION SITE", 25th IEEE Canadian Conference on Electrical and Computer Engineering (CCECE).

[2] El Badawe & M. Iqal T George M, (2011) "Optimal sizing and modeling of a hybrid energy system for a remote telecommunication facility " presented at IEEE 21 NECEC conference St ohn's NF.

[3] Ross M, Hidalgo R & Abbey C, Joos G, (2010) "Analysis of Energy Storage sizing and technologies" Electric Power and Energy Conference (EPEC), vol., no., pp.1-6, 2527Aug.2010.

[4] P. Nema et al, (2009)"A current and future state of art development of hybrid energy system using wind and PV-solar: A review." Renewable and Sustainable Energy Reviews 13, 2096–2103.

[5] Wind turbine manufacturer [Online]. Available at http://msmelectric.com/montage/catalog/.

[6] Photovoltaic panels manufacturer [Online]. Available at http://www.wholesalesolar.com/products.

[7] Manufacture and worldwide distributor of long-lasting deep-cycle batteries [Online]. Available at www.trojanbattery.com.

[8] BolfazlShiroudi & Seyed Reza HosseiniTaklimi, (2011) "Demonstration project of the solar hydrogen energy system loc Taleghan-Iran: Technical-economic assessments" World Renewable Energy Congress - Sweden.

[9] Souissi Ahmed & Hasnaoui Othman & SallamiAni,(2010) "Optimal Sizing of a Hybrid System of Renewable Energy for a Reliable Load Supply without Interruption" European Journal of Scientific ResearchISSN 1450-216X Vol.45 No.4,pp.620-629

[10] NASA Surface Meteorology and Solar Energy [Online]. Available at http://www.nasa.gov

[11] Sureshkumar, Manoharan, P.S. ; Ramalakshmi,(2012) "Economic cost analysis of hybrid renewable energy system using HOMER" IEEE- International Conference On Advances In Engineering, Science And Management (ICAESM -2012) March 30, 31, 2012